ROTIFER COMMUNITIES OF FLOODPLAIN LAKES OF MANIPUR (NORTH-EAST INDIA): BIODIVERSITY, DISTRIBUTION AND ECOLOGY

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The rotifer communities of fifteen slightly acidic-circumneutral, soft water floodplain lakes (*pats*) of Manipur, with low ionic concentrations; revealed 151 species of Rotifera belonging to 42 genera and 22 families. Biogeographically interesting elements include two Australasian, four Oriental, eight Palaeotropical, one Holarctic and one Arctic-temperate species. Cosmopolitan species form a notable component (67.5%) while Cosmotropical > Pantropical species are well-represented. Lecanidae (40 species) > Lepadellidae (25 species) > Trichocercidae (15 species) > Brachionidae (14 species) comprise an important fraction (62.25%) of the documented species The rotifer fauna is characterised by dominance of *Lecane* spp., occurrence of several acidophilus species, paucity of *Brachionus* spp. and general tropical character. Richness ranges between 62 and 120 (73 ±14) species in individual *pats*, registers 53.0-87.9% community similarities (*vide* Sorensen index) and shows wider seasonal variations (29-79 species) in different *pats*. The rotifers form an important quantitative component (mean: 45.9-58.8%) of zooplankton in all lakes. ANOVA indicates a significant temporal variation of richness and density between lakes and seasons. Richness is inversely correlated with water temperature. The density is inversely correlated with specific conductivity and alkalinity, and positively correlated with hardness. Canonical analysis registers moderate and relatively higher cumulative impact of six abiotic factors on richness and density respectively. The rotifer communities of the sampled *pats* are characterised by relatively high species diversity, lower dominance and higher evenness.

Key words: Floodplain lakes, Manipur, Rotifera, biodiversity, distribution, ecology

INTRODUCTION

The floodplain lakes, an integral part of various riverine systems of the world, harbour the richest aquatic biodiversity and are considered to be the most productive freshwater biotopes (Odum 1978; Mitsch and Gosselink 1986). They form an important inland aquatic resource of India in general, and that of N.E. India in particular. The floodplain lakes, commonly called '*pats*' in Manipur, are located in the Iral, Imphal and Thoubal river basins. They cover an area of 16,500 ha and play a vital role in the socio-economic development of the state because of their significant biogenic production potential. These interesting ecotones are facing severe environmental stress due to general habitat degradation, influx of waste water and encroachment of land for expanding human settlements, and increasing pressures for converting them into agricultural lands. Hence, conservation of these valuable wetlands and of their biological diversity deserves priority attention.

The investigations on aquatic biodiversity in India began nearly a century ago. The published literature indicates limited information on composition and ecology of invertebrate, and zooplankton communities in the floodplain lakes of this country (Sharma and Sharma 2008). The studies on zooplankton diversity of the floodplain lakes of N.E. region in particular, are mainly initiated in beels of the Brahmaputra basin (Sharma and Sharma 2001, 2008; Sharma 2005). On the other hand, the contributions in the floodplain lakes of Manipur are so far restricted to a preliminary unpublished list of Shyamananda Singh (1991) and new records of Rotifera (Sharma 2007).

The present study on Rotifera, the most diverse group of zooplankton, of the floodplain lakes or '*pats*' of Manipur, therefore, assumes special biodiversity and ecological interest. The rotifer communities of fifteen lakes of this state are analyzed with reference to species richness, community similarities, and general nature and composition of their taxocoenosis. Remarks are made on biogeographically interesting elements and on distribution of various species. In addition, variations in richness and abundance are recorded and comments are made on species diversity, dominance, evenness and ecology of Rotifera.

MATERIAL AND METHODS

The observations were undertaken in fifteen floodplain lakes (*pats*) of the Iral, Imphal and Thoubal river basins (24° 25'-24° 45' N; 93° 45'-94° 00' E), located in Bishnupur, Imphal and Thoubal districts of Manipur respectively (Table 1).

Water samples collected seasonally from different *pats*, during the study period November 2002-October 2003, were analyzed for water temperature, specific conductivity, pH, dissolved oxygen, alkalinity and hardness. Plankton samples were collected seasonally for qualitative (by towing) and

Table 1: Districts of Manipur representing floodplain lakes (*pats*) selected for the study area

Sr. No.	Name of Lake (*pat*)	District
1	Loktak	Bishnupur / Imphal
2	Waithou	Thoubal
3	Utra	Bishnupur
4	Sana	Bishnupur
5	Lakoi	Bishnupur
6	Takmu	Bishnupur
7	Ikop	Thoubal
8	Kharung	Thoubal
9	Khoidum	Thoubal
10	Pumlen	Thoubal
11	Lousi	Thoubal
12	Karam	Thoubal
13	Ngagua	Thoubal
14	Tankha	Imphal
15	Lamphel	Imphal

quantitative (by filtering 25 litre water) analysis from various lakes with a nylobolt plankton net (mesh size: 50 µm), during the study period, and were preserved in 5% formalin. The Rotifera species were identified following Koste (1978), Segers (1995), Sharma (1998a), and Sharma and Sharma (1999, 2000, 2008). Remarks on the distribution were made *vide* Segers (2007). Quantitative plankton samples were analyzed for enumeration of the rotifer densities (n/l).

Community similarities (Sorensen index), species diversity (Shannon index), dominance (Berger-Parker index) and evenness (Pileou index) were calculated following Ludwig and Reynolds (1988) and Magurran (1988). The significance of temporal variations of richness and densities were ascertained by ANOVA. Canonical analysis (STATISTICA version 5.0) was undertaken for simple and multivariate correlations.

RESULTS AND DISCUSSION

Water temperature (13.1-30 °C) affirms the subtropical nature of different *pats*. Specific conductivity (36.0-200 µS/cm) shows low ionic concentrations (Table 2) and warrants their inclusion under 'Class I' category of 'trophic classification' of Talling and Talling (1965). All the sampled *pats* are characterised by slightly acidic-circumneutral waters (pH: 5.70-6.92) with mean pH values ranging between 6.02-6.44. Dissolved oxygen ranges between 2.4-12.0 mg/l.

Rotifers form the most diverse qualitative group of zooplankton in all the lakes in the study area and include a total of 151 species, which comprise 39.7% of the Indian Rotifera and 70% of the species known from N.E. India. Further, this study exhibits higher diversity, i.e., 42 genera and 22 families of this Phylum known till date from floodplain lakes or other aquatic ecosystems of India. This salient feature deserves special mention in view of 46 and 67 genera, as well as 24 and 25 families, of Eurotatoria respectively so far reported from N.E. India (Sharma, unpublished). The present results reflect rich, speciose and diverse nature of Rotifera and, hence, reflect greater environmental heterogeneity of the sampled *pats*. These features concur with the composition of the rotifer communities of the floodplains of Argentina (Jose de Paggi 1993), South America (Bonecker *et al.* 1998) and Australia (Shiel *et al.* 1998). This study affirms the hypothesis of Segers *et al.* (1993) indicating (sub) tropical floodplains to be the world's richest habitats for rotifers, and also endorses earlier studies (Sharma 2005; Sharma and Sharma 2008) in the floodplain lakes of the Brahmaputra river basin.

The Rotifera biodiversity of the sampled lakes is lower than the reports of 207, 218 and 252 species from the floodplain lakes of Africa (Segers *et al.* 1993), South America (Bonecker *et al.* 1998) and Australia (Shiel *et al.* 1998) respectively. The richness however, is marginally lower than the 164 species examined from fifteen floodplain lakes from the Brahmaputra river basin of Assam (Sharma 2005) while it is higher than 127 species listed from other fifteen beels of Assam (Sharma and Sharma 2008). The present report of the rotifer richness in the floodplain lakes of Manipur, however, is distinctly higher to the records of 64 species (Sharma 2000), 29 species (Goswami 1997) and 48 species (Sarma 2000) from the beels of Assam and 43 species (Khan 2003) from the floodplains of south-east West Bengal.

Interestingly, Loktak lake – a Ramsar site and one of the largest freshwater wetlands of India, exhibits the highest Rotifera richness (120 species) known till date from any individual aquatic ecosystem of the Indian subcontinent in general and floodplain lake, in particular. The numbers also exceed the recent highest record of 110 species (Sharma and Sharma 2005b) from Deepor beel, a Ramsar site and another important wetland of N.E. India. Rotifera richness of Loktak compares well with the report of 124 species from Oguta lake of Niger delta (Segers *et al.* 1993); 111 species (Jose de Paggi 1993) and 114 species (Jose de Paggi 2001) examined from floodplain lakes of Argentina; 136 species from Iyi-Efi lake of the Niger delta (Segers *et al.* 1998); and 130 species from Lake Guaraná, Brazil (Bonecker *et al.* 1994).

The present study reveals sixteen biogeographically interesting species (10.6%) belonging to the following categories:

1. Australasian species: *Macrochaetus danneeli* and *Notommata spinata*

2. Oriental species: *Filinia camasecla*, *Lecane acanthinula*, *L. blachei* and *L. solfatara*

3. Palaeotropical species: *Euchlanis semicarinata*, *Lecane lateralis*, *L. simonneae*, *L. unguitata*, *Lepadella bicornis*, *L. discoidea*, *Testudinella brevicaudata* and *Trichocerca abilioi*

4. Arctic-Temperate: *Lecane scutata*

5. Holarctic: *Lecane elongata*

The report of two Australasian species, a notable feature of this study, depicts an interesting affinity between the rotifer faunas of the N.E. India with that of South-east Asia and Australia. Of these, *Macrochaetus danneeli* is reported from Australia and Thailand. Segers and Sarma (1993) mentioned its occurrence in southern India based on an unpublished report, but the record from Assam (Sharma 2004) indicates its only confirmed report from India and second report from Asia. *Notommata spinata*, resurrected as a distinct species by Koste and Shiel (1991), occurs in Australia and is now known from India only from Assam (Sharma 2005).

The occurrence of four Oriental species is another salient feature of the rotifer fauna of the sampled *pats*. Among these, *Filinia camasecla* and *Lecane solfatara* are so far known only from N.E. India (Sharma and Sharma 2008), *L. blachei* is reported from Eastern and North-east India and *L. acanthinula* exhibits disjunct distribution in this country with reports from Southern and North-Eastern India (Sharma and Sharma 2005a).

Amongst the Palaeotropical species, the erstwhile Afro-tropical *Euchlanis semicarinata* examined from Loktak lake, Manipur (Sharma 2007) is an interesting recent addition to the Indian Rotifera. *Lecane simonneae* is reported from India only from Tripura (Sharma and Sharma 1997) while *Lepadella discoidea*, *Testudinella brevicaudata* and *Trichocerca abilioi* are known from Assam in N.E. India. *Lecane lateralis*, described originally from West Bengal (Sharma 1978), is a widely known palaeotropical element. *Lepadella bicornis*, described by Vasisht and Battish (1971) from Chandigarh, north India is known only from Brazil; its recent record from Assam (Sharma and Sharma *in press*) represents the second Indian report of this lecanid since its description. *Lecane unguitata* is widely distributed in India.

Table 2: Abiotic factors of *pats* of Manipur

Abiotic Factors	Water temp. (° C)	Specific conductivity (µS/cm)	pH	Dissolved oxygen (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)
Loktak	14.2-28.5 (21.8 ±4.2)	66.0-132.0 (93.3 ±17.1)	5.70-6.92 (6.31 ±0.32)	4.2-9.0 (5.7 ±1.1)	10.0-41.2 (19.1 ±7.1)	24.0-54.0 (38.3 ±7.8)
Waithou	14.5-29.2 (21.6 ±4.8)	52.0-120.5 (92.3 ±16.8)	5.59-6.60 (6.21 ±0.28)	2.4-12.0 (5.3 ±2.8)	10.0-36.2 (19.7 ±5.6)	20.1-56.0 (33.6 ±7.8)
Utra	16.2-27.9 (22.2 ±3.5)	48.0-120.5 (77.2 ±21.6)	5.40-6.68 (6.23 ±0.32)	4.0-10.0 (6.0 ±1.4)	10.0-44.0 (19.5 ±9.4)	20.0-46.0 (33.0 ±7.4)
Sana	13.1-28.5 (21.2 ±5.2)	69.3-107.0 (80.2 ±8.3)	6.12-6.78 (6.37 ±0.14)	4.8-7.9 (5.4 ±2.6)	25.1-38.5 (29.2 ±4.1)	19.2-32.5 (25.9 ±3.7)
Lakoi	14.5-29.0 (22.1 ±4.9)	41.8-82.0 (61.4 ±5.9)	6.15-6.81 (6.37 ±0.12)	5.2-9.0 (6.6 ±2.2)	12.0-36.0 (24.2 ±4.9)	10.0-34.2 (20.4 ±4.6)
Takmu	15.1-28.2 (22.6 ±3.1)	79.5-128.0 (100.5 ±8.6)	5.89-6.86 (6.02 ±0.34)	4.2-10.0 (5.8 ±2.1)	16.0-39.4 (21.4 ±5.3)	15.4-48.0 (24.9 ±5.1)
Ikop	13.9-21.6 (21.3 ±5.5)	124.1-200.0 (168.7 ±13.9)	6.18-6.77 (6.39 ±0.12)	4.0-9.2 (6.9 ±1.8)	22.3-50.0 (30.4 ±5.9)	18.0-48.4 (24.9 ±5.8)
Kharung	14.0-28.5 (21.0 ±4.0)	36.0-68.0 (46.0 ±5.1)	5.91-6.89 (6.30 ±0.29)	6.0-9.0 (7.2 ±1.6)	26.2-48.0 (32.4 ±4.2)	22.0-44.2 (30.0 ±4.7)
Khoidum	12.4-27.6 (22.8 ±4.7)	72.4-100.0 (87.9 ±7.2)	5.92-6.62 (6.22 ±0.13)	4.4-8.4 (5.8 ±2.1)	21.4-32.6 (25.8 ±3.9)	14.0-29.4 (18.3 ±3.3)
Lousi	14.5-27.9 (21.7 ±4.1)	94.2-149.0 (121.2 ±9.0)	6.12-6.89 (6.44 ±0.14)	5.2-10.4 (6.5 ±2.6)	12.0-35.4 (24.1 ±4.3)	14.0-36.0 (23.9 ±3.7)
Karam	12.9-28.0 (20.7 ±4.1)	78.1-108.0 (80. 8 ±6.7)	5.72-6.48 (6.16 ±0.10)	4.2-8.8 (6.4 ±1,2)	18.4-29.4 (23.1 ±2.1)	16.2-28.0 (21.1 ±3.2)
Ngagua	14.0-29.2 (22.2 ±3.6)	105.4-183.0 (134.2 ±16.7)	6.12-6.78 (6.43 ±0.11)	5.6-7.8 (6.4 ±1.3)	20.1-38.8 (32.2 ±3.9)	16.2-29.6 (20.7 ±3.9)
Tankha	14.0-29.0 (22.0 ±4.0)	87.0-125.0 (105.1 ±6.6)	6.01-6.77 (6.37 ±0.13)	6.2-9.6 (6.8 ±2.4)	25.2-48.0 (30.3 ±4.0)	16.8-39.1 (26.0 ±4.4)
Lamphel	13.5-28.7 (21.4 ±3.5)	153.0-200.0 (177.4 ±9.3)	6.12-6.86 (6.38 ±0.12)	5.4-9.8 (6.0 ±2.5)	18.4-38.0 (27.8 ±4.2)	16.8-36.2 (26.2 ±4.2)
Pumlen	13.5-30.0 (21.5 ±4.2)	98.4-127.0 (107.8 ±5.3)	5.82-6.78 (6.26 ±0.16)	6.2-9.0 (7.0 ±1.8)	12.5-37.4 (21.6 ±4.3)	10.2-30.2 (20.6 ±3.7)

Note: Mean values given in parentheses

Table 3: Rotifera of floodplain lakes (*Pats*) of Manipur

Recorded taxa \ Floodplain lakes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Order: Ploima																
Family: Brachionidae																
Anuraeopsis fissa Gosse	+	-	+	-	-	+	-	+	+	-	-	+	+	+	-	R
Brachionus angularis Gosse	+	+	+	+	+	+	+	+	-	+	+	-	+	+	+	C
B. bidentatus Anderson	-	-	+	+	+	-	+	+	-	-	+	+	+	-	+	C
B. calyciflorus Pallas	+	-	-	-	-	-	-	-	-	+	+	-	-	-	-	R
B. diversicornis (Daday)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	R
B. falcatus Zacharias	+	+	+	+	+	+	+	+	+	-	+	-	+	+	+	C
B. forficula Wierzejski	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	R
B. mirabilis Daday	+	-	+	-	-	-	+	+	+	+	-	+	-	-	+	R
B. quadridentatus Hermann	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
Keratella cochlearis (Gosse)	+	+	+	-	+	-	+	+	+	+	+	+	+	+	+	C
K. lenzi Hauer	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	R
K. tropica (Apstein)	+	-	-	+	+	+	-	+	+	+	-	+	+	+	-	C
Platyias quadricornis (Ehrenberg)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
Plationus patulus (O.F. Müller)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
P. patulus macracanthus (Daday)	+	+	+	-	-	+	+	+	+	+	+	-	+	+	-	C A
Family: Epiphanidae																
Epiphanes brachionus (Ehrenberg)	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	R
Family: Euchlanidae																
Euchlanis dilatata Ehrenberg	+	+	+	-	+	+	+	+	+	-	+	+	+	+	+	C
E. incisa Carlin	-	-	-	+	+	-	+	+	+	+	-	+	+	+	+	R
E. oropha Gosse	-	-	-	+	-	-	+	+	-	-	+	-	+	-	-	R
E. semicarinata Segers	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
E. triquetra Ehrenberg	+	+	+	+	-	+	+	-	+	+	-	+	+	-	+	R A
Dipleuchlanis propatula (Gosse)	+	+	+	+	-	+	+	+	+	-	+	+	-	+	-	C A
Beauchampiella eudactylota (Gosse)	+	-	+	-	+	+	+	+	-	+	+	+	+	+	+	C
Family: Mytilinidae																
Lophocharis salpina (Ehrenberg)	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-	R
Mytilina bisulcata (Lucks)	+	+	-	-	-	-	-	+	-	-	+	+	-	+	-	R A
M. ventralis (Ehrenberg)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
Family: Trichotriidae																
Macrochaetus danneeli Koste & Shiel	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
M. longipes Myers	+	+	-	+	+	-	+	-	+	+	+	+	-	-	+	R
M. sericus (Thorpe)	+	+	+	-	-	+	+	+	-	-	-	+	+	+	-	C
Trichotria tetractis (Ehrenberg)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
Family: Lepadellidae																
Colurella adriatica Ehrenberg	-	-	-	+	-	-	-	+	+	-	+	-	-	+	-	R
C. obtusa (Gosse)	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	C
C. sulcata (Stenroos)	+	-	-	+	+	-	-	+	-	-	-	-	-	+	+	R A
C. uncinata (O.F. Müller)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C A
Lepadella acuminata (Ehrenberg)	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	C
L. apsicora Myers	+	-	-	+	+	+	+	+	-	-	+	-	+	-	+	R
L. apsida Harring	+	+	+	-	+	-	+	+	+	-	-	-	+	+	+	R
L. bengamini Harring	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	R
L. bicornis Vasisht & Battish	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	R
L. biloba Hauer	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	R
L. costatoides Segers	+	-	-	-	-	-	-	+	-	+	-	-	+	-	-	R
L. cristata (Rousselet)	-	-	-	+	-	-	+	-	-	-	-	+	-	+	-	R A
L. dactyliseta (Stenroos)	+	-	-	+	+	-	-	-	-	+	-	+	-	+	-	R
Lepadella discoidea Segers	-	-	-	+	-	+	-	-	-	-	+	-	-	-	-	R

Table 3: Rotifera of floodplain lakes (*Pats*) of Manipur (*contd.*)

Recorded taxa \ Floodplain lakes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
L. ehrenbergi (Perty)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
L. eurysterna Myers	+	-	-	-	+	-	-	+	+	-	+	-	+	-	+	R
L. heterostyla (Murray)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
L. latusinus (Hilgendorf)	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	R
L. lindaui Koste	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
L. ovalis (O.F. Müller)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
L. patella (O.F. Müller)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
L. rhomboides (Gosse)	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	C
L. triba Myers	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
L. triptera Ehrenberg	+	+	+	-	-	+	+	+	-	+	+	+	-	+	+	R A
Squatinella mutica (Ehrenberg)	+	-	-	+	+	-	+	+	-	-	-	+	+	+	-	R
Family: Lecanidae																
Lecane acanthinula (Hauer)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
L. aculeata (Jakubski)	+	+	+	-	-	-	-	+	+	-	+	+	+	+	+	R
L. blachei Berzins	+	-	-	+	-	-	-	-	+	-	-	-	+	-	+	R
L bulla (Gosse)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
L. closterocerca (Schmarda)	+	+	+	-	+	+	+	+	-	+	+	+	+	+	+	C
L. crepida Harring	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	C
L. curvicornis (Murray)	+	+	+	-	+	+	-	+	+	+	+	+	+	+	+	C
L. decipiens (Murray)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	R
L. doryssa Harring	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	R A
L. elegans Harring	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
L. elongata Harring & Myers	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	R
L. flexilis (Gosse)	+	-	+	-	+	+	-	+	-	-	+	-	+	-	+	R
L. furcata (Murray)	+	+	+	+	-	-	-	-	+	-	+	-	+	+	+	R
L. haliclysta Harring & Myers	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	R
L. hamata (Stokes)	+	+	+	-	+	-	+	+	+	+	-	+	+	+	+	C
L. hastata (Murray)	-	-	-	+	-	+	-	-	-	+	-	-	-	-	+	R
L. hornemanni (Ehrenberg)	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	C
L. inermis (Bryce)	+	+	+	+	+	+	+	+	+	-	-	+	+	+	-	C
L. inopinata Harring & Myers	+	-	-	-	-	+	-	-	+	-	-	+	-	-	+	R
L. lateralis Sharma	+	-	-	-	+	-	+	-	-	-	-	+	-	-	-	R
L. leontina (Turner)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
L. ludwigii (Eckstein)	+	+	+	+	-	+	+	-	+	+	-	-	-	+	-	R
L. luna (O.F. Müller)	+	+	+	-	+	-	+	+	+	+	+	+	+	-	+	C
L. lunaris (Ehrenberg)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
L. monostyla (Daday)	+	+	-	+	-	-	-	-	+	-	-	-	+	+	-	R
L. obtusa (Murray)	+	+	+	-	-	-	-	+	-	-	+	-	-	-	+	R
L. ohioensis (Herrick)	+	+	+	-	-	-	+	-	-	-	-	+	-	+	-	R
L. papuana (Murray)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
L. ploenensis (Voigt)	+	+	+	-	-	+	+	+	+	-	+	+	+	+	-	C
L. quadridentata (Ehrenberg)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
L. ruttneri Hauer	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
L. scutata (Harring & Myers)	-	-	-	-	+	-	+	-	-	-	-	-	+	-	-	R A
L. signifera (Jennings)	+	+	+	+	+	+	+	+	-	+	-	+	+	+	+	C
L. simonneae Segers	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
L. solfatara (Hauer)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
L. stenroosi (Meissner)	+	+	+	+	-	+	+	+	+	+	+	+	-	+	+	C
L. tenuiseta Harring	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
L. thienemanni (Hauer)	-	-	-	+	+	-	+	-	-	-	-	-	+	-	+	R
L. unguitata (Fadeev)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
L. ungulata (Gosse)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C

Table 3: Rotifera of floodplain lakes (*Pats*) of Manipur (*contd.*)

Recorded taxa \ Floodplain lakes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Family: Notommatidae																
Cephalodella forficula (Ehrenberg)	+	+	-	+	-	+	+	-	-	+	+	+	+	-	+	R
C. gibba (Ehrenberg)	+	+	-	-	+	+	-	+	-	-	-	+	-	-	+	R
C. mucronata Myers	+	-	-	-	+	-	+	+	-	-	-	-	-	-	-	R
Monommata longiseta (O.F. Müller)	+	-	-	+	-	-	-	-	+	+	-	+	+	+	-	R A
M. maculata (Harring & Myers)	+	-	-	-	-	+	-	-	+	-	-	-	-	-	+	R A
Monommata sp.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
Notommata spinata Koste & Shiel	+	-	-	-	-	-	-	+	-	-	-	-	+	-	-	R
Taphrocampa annulosa (Gosse)	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	R
Family: Scaridiidae																
Scaridium longicaudum (O.F. Müller)	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	C
Family: Gastropodidae																
Ascomorpha ecaudis Perty	+	-	-	+	-	-	-	-	-	-	-	-	+	-	-	R
A. ovalis (Bergendal)	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	R
Family: Trichocercidae																
Trichocerca albiloi Segers & Sarma	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	R
T. bicristata (Gosse)	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	R
T. capucina (Wierzejski & Zacharias)	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	R
T. cylindrica (Imhof)	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	C
T. elongata (Gosse)	+	+	-	+	-	-	-	+	-	+	-	+	+	-	-	R
T. flagellata Hauer	+	-	-	-	+	-	-	-	-	-	+	-	-	-	-	R
T. insignis (Herrick)	+	-	-	+	-	+	-	-	-	-	-	-	+	-	-	R
T. jenningsi Voigt	+	+	-	+	-	-	-	-	+	-	-	-	-	-	+	R
T. longiseta (Schrank)	+	+	+	+	+	-	+	+	+	+	-	+	-	+	-	C
T. pusilla (Jennings)	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	R
T. rattus (O.F. Müller)	+	+	+	-	+	+	+	+	+	+	+	-	+	-	+	C
T. ruttneri Donner	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	R
T. similis (Wierzejski)	+	+	+	-	+	-	+	+	+	-	+	+	+	+	+	C
T. sulcata (Jennings)	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	R
T. tenuior (Hudson & Gosse)	+	-	-	-	+	-	-	+	-	-	-	-	-	+	-	R
Family: Asplanchnidae																
Asplanchna priodonta Gosse	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
Family: Synchaetidae																
Pleosoma lenticulare Herrick	+	-	-	-	+	-	-	+	-	-	+	-	-	-	-	R
Polyarthra vulgaris Carlin	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
Synchaeta pectinata Ehrenberg	+	-	-	+	-	-	-	-	-	-	-	-	+	-	-	R
S. oblonga Ehrenberg	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	R
Family: Dicranophoridae																
Dicranophorus caudatus (Ehrenberg)	+	-	-	-	-	-	-	+	-	-	-	-	-	+	+	R
D. forcipatus (O.F. Müller)	+	-	-	+	-	-	-	-	-	-	+	-	-	-	-	R
Order: Flosculariaceae																
Family: Flosculariidae																
Floscularia ringens (Linnaeus)	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	R
Sinantherina socialis (Linnaeus)	+	+	-	-	+	+	+	-	+	+	+	+	+	-	+	C
S. spinosa (Thorpe)	+	+	-	+	+	+	+	+	+	+	+	+	+	-	+	C
Family: Conochilidae																
Conochilus unicornis Rousselet	+	+	+	-	-	+	+	+	+	+	-	+	+	+	+	C

Table 3: Rotifera of floodplain lakes (*Pats*) of Manipur (*contd.*)

Recorded taxa \ Floodplain lakes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Family: Trochosphaeridae																
Filinia brachiata (Rousselet)	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	R
F. camasecla Myers	+	-	-	-	+	-	+	-	+	-	-	-	-	-	+	R
F. longiseta (Ehrenberg)	+	+	+	+	+	+	-	+	+	+	-	+	+	+	+	C
F. opoliensis (Zacharias)	+	+	+	-	-	+	-	+	-	+	-	+	-	-	-	R
F. saltator (Gosse)	+	-	-	+	-	-	+	-	-	-	+	-	-	-	-	R
Trochosphaera aequatorialis Semper	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	R
Family: Testudinellidae																
Testudinella brevicaudata Yamamoto	+	-	-	-	-	-	+	+	-	-	-	-	-	-	-	R
T. emarginula (Stenroos)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C A
T. parva (Ternetz)	+	-	-	-	-	-	-	+	+	+	-	+	-	+	-	R A
T. patina (Hermann)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
T. tridentata Smirnov	+	+	+	-	-	-	-	-	-	+	+	-	-	-	+	R A
Order: Collothecaceae **Family**: Collothecidae																
Collotheca ornata (Ehrenberg)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	R
Order: Bdelloidea **Family**: Adinetidae																
Adineta vaga (Davis)	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	R
Family: Habrotrochidae																
Habrotrocha angusticollis (Murray)	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	R
Family: Philodinidae																
Macrotrachela multispina Thompson	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	R
Philodina citrina (Ehrenberg)	+	+	-	-	-	-	-	-	-	+	-	-	-	-	+	R
Rotaria macroceros (Gosse)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	R
R. neptunia (Ehrenberg)	+	+	+	-	-	-	-	+	-	-	+	+	-	+	-	R
R. rotatoria (Pallas)	+	-	+	+	-	-	-	+	+	-	+	-	+	-	+	R
R. tardigrada (Ehrenberg)	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	R
No. of Species of Rotifera	120	68	66	69	63	62	70	82	67	62	70	72	75	70	73	

1-Loktak *Pat*, 2-Waithou *Pat*, 3-Utra *Pat*, 4-Sana *Pat*, 5-Lakoi *Pat*, 6-Takmu *Pat*, 7-Ikop *Pat*, 8-Kharung *Pat*, 9-Khoidum *Pat*, 10-Lousi *Pat*, 11-Karam *Pat*, 12-Ngagua *Pat*, 13-Tankha *Pat*, 14-Lamphel *Pat*, 15-Pumlen *Pat*.
'+' Present, '-' Absent, C-Common, R-Rare, A-Acidophilus

Of the two other biogeographically interesting species, *Lecane scutata* is distributed in India in the states of Assam, Meghalaya, Tripura and West Bengal (Sharma and Sharma 2008) while the Holarctic *L. elongata* is recorded recently (Sharma and Sharma *in press*) from Assam.

Lecanidae (40 species) > Lepadellidae (25 species) > Trichocercidae (15 species) > Brachionidae (14 species), in the stated order, comprise an important fraction (62.25%) of the rotifer diversity. The qualitative significance of these eurotatorian families broadly concurs with the results from the floodplains of South America (Jose de Paggi 1993, 2001; Bonecker *et al.* 1994, 1998; Segers *et al.* 1998), Africa (Segers *et al.* 1993) and Thailand (Sanoamuang 1998). This generalization, however, differs from the floodplains of Assam (Sharma 2005; Sharma and Sharma 2008) in occurrence of a fewer species of the Brachionidae. Besides, six other monogonont families namely Notommatidae > Euchlanidae > Trochosphaeridae > Philodinidae = Testudinellidae, together, form a valuable component (21.2%) of Rotifera of the *pats* of Manipur.

Cosmopolitan species form an important component (65.6%) of the rotifer diversity while Cosmotropical > Pantropical species together comprise 23.6%. The members of the last two categories as well as qualitative dominance of 'tropic-centered' genus *Lecane* impart a 'tropical character' to the rotifer fauna of the floodplain lakes of Manipur. This feature concurs with the composition of the tropical faunas from different parts of the globe (Green 1972; Pejler 1977;

Fernando 1980; Dussart *et al.* 1984; Segers 1996; Sharma 1998b). In general, the lecanid dominance compares well with the floodplain rotifer communities studied by Segers *et al.* (1993, 1998), Sanoamuang (1998) and Jose de Paggi (2001). The present results are, however, characterised by distinct paucity of an important tropic-centered' genus *Brachionus* which, in turn, includes only eight species and a number of them even exhibit rare or restricted occurrence; these features are attributed to slightly acidic-circumneutral character of the sampled *pats*. In addition, the rotifer communities show importance of *Lepadella* (20 species) > *Trichocerca* (15 species). Thus, the four mentioned monogonont genera comprise the bulk of species reported from the floodplain lakes of Manipur (83 species, 53%). On the other hand, the occurrence of fewer species of 'temperate-centered' *Keratella* (3 species) and cold-water *Synchaeta* (2 species) and, the lack of any member of *Notholca* are noteworthy.

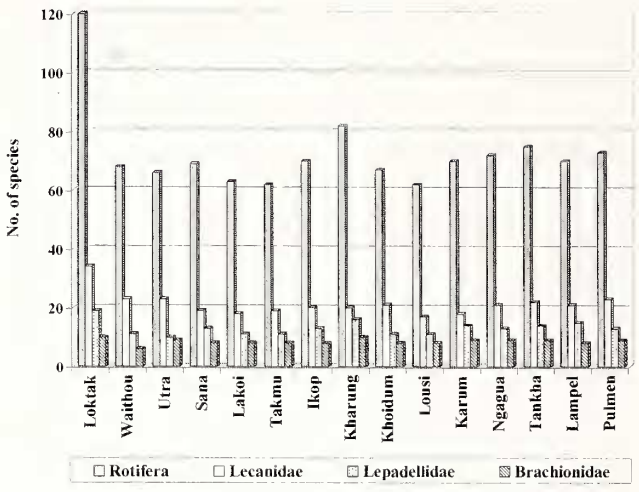

Fig. 1: Species richness of Rotifera and dominant families

This study indicates occurrence of fifteen (9.9%) acidophilus elements, namely *Plationus patulus macracanthus*, *Dipleuchlanis propatula*, *Euchlanis triquetra*, *Mytilina bisulcata*, *Colurella sulcata*, *Lepadella acuminata*, *L. cristata*, *L. triptera*, *Lecane doryssa*, *L. pertica*, *L. scutata*, *Monommata longiseta*, *M. maculate*, *Testudinella emarginula*, *T. parva* and *T. tridentata*. Fifty-one species (23.8%) exhibit common occurrence with 21 species (13.9%) occurring in all the *pats* (Table 3). On the other hand, 101 species (66.0%) show restricted occurrence while 24 (15.9%) of them are rare elements. The rotifer communities of the *pats* of Manipur register 74.5% similarity (*vide* Sorensen's index) with the species known from the beels of Assam. The differences are apparently due to distinct paucity of the Brachionidae in general, and *Brachionus* spp. in particular. Strikingly, lack of species of *Hexarthra*, *Pompholyx* and *Horaella*, and rare nature species of *Conochilus*, *Trochosphaera* and *Filinia* are noteworthy features of the present observations.

The rotifer communities are characterised by the occurrence of a high number of small taxa although species of the higher size classes are also noticed. The former interesting feature may be assigned to conditions of low concentrations of food, and predation by fish and invertebrates as suggested by Papinski (1990) and Baumgartner *et al.* (1997) respectively, but specific investigations are desired to confirm these remarks. The predominance of the littoral periphytic

Table 4: Percentage similarities between Rotifer communities (Sorensen's index)

Floodplain lakes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Loktak	-	65.7	64.3	57.6	60.4	64.0	63.0	72.0	65.0	61.4	62.3	66.3	67.6	65.3	67.0
Waithou		-	87.9	61.2	62.5	76.6	77.9	76.2	79.7	78.1	77.0	82.6	75.7	80.0	79.1
Utra			-	53.0	65.1	73.0	83.6	87.4	77.9	77.8	75.2	79.4	78.3	81.2	77.4
Sana				-	57.8	54.4	63.2	57.1	64.7	60.9	59.2	60.9	60.0	63.7	60.4
Lakoi					-	63.9	72.3	69.5	64.6	62.3	63.6	65.1	71.6	65.1	70.7
Takmu						-	70.8	70.9	67.7	73.8	68.2	74.2	71.6	71.3	73.4
Ikop							-	76.5	71.1	72.3	70.1	77.1	74.6	73.0	75.2
Kharung								-	74.0	73.8	74.3	78.1	78.4	81.1	75.0
Khoidum									-	72.4	65.7	75.9	74.8	74.6	74.6
Lousi										-	66.7	78.8	71.6	69.8	75.5
Karam											-	67.6	70.9	66.2	72.8
Ngagua												-	75.0	80.6	71.3
Tankha													-	73.7	80.8
Lamphel														-	68.6
Pumlen															-

1-Loktak *Pat*, 2-Waithou *Pat*, 3-Utra *Pat*, 4-Sana *Pat*, 5-Lakoi *Pat*, 6-Takmu *Pat*, 7-Ikop *Pat*, 8-Kharung *Pat*, 9-Khoidum *Pat*, 10-Lousi *Pat*, 11-Karam *Pat*, 12-Ngagua *Pat*, 13-Tankha *Pat*, 14-Lamphel *Pat*, 15-Pumlen *Pat*

species and presence of fewer planktonic elements in the examined collections may be attributed to the lack of definite pelagic habitats (De Manuel 1994) in the floodplain lakes. Besides, the occurrence of both planktonic and non-planktonic taxa in the *pats* with marginal vegetation suggests the occupation of different niches (Bonecker *et al.* 1998).

Total Rotifera richness (Fig. 1) in different Manipur lakes varies between 62 and 120, (73 ±14 species); it shows relatively broad range while mean value corresponds with the earlier reports of 67-103 (79 ±11 species) and 69-92 (75 ±6 species) from the beels of the Brahmaputra river basin (Sharma 2005; Sharma and Sharma 2008). The present results are, however, significantly higher than the reports of 24-35 (30 ±4) species and 54-65 (56 ±3) species recorded from five (Sharma 2000) and seven beels (Sharma and Sharma 2001) of Assam respectively. Lecanidae (21 ±4 species) > Lepadellidae (13 ±2 species) > Brachionidae (8 ±1 species) together contribute notably (Fig. 1) to the faunal diversity in individual *pats*. The rotifer communities of the different lakes indicate 53.0-87.9% similarity (*vide* Sorensen index). The peak similarity is noticed between Waithou and Utra *pats* while lowest value is observed between Utra and Sana *pats*. Further, Sana *pat* records the lowest similarity range (53.0-64.7%). Only 5.7% and 6.7% of instances in the matrix (Table 4) indicate similarity values < 60% and > 80% respectively, while in majority of instances (87.6%) the similarity varies between 60-80%. The cluster analysis (Fig. 2) reflects higher similarities in the Rotifera of Waithou and Utra *pats*, Ngagua and Lamphel *pats* and, Tankha and Pumlen *pats*, while Karam, Loktak, Lakoi and Sana *pats* are categorized by differences in their species composition.

Richness depicts significant temporal variations in different seasons ($F_{3.59} = 12.603$, $P < 0.005$) and in different *pats* ($F_{14.59} = 5.585$, $P < 0.005$). Further, it shows notable variations (29-79 species) in individual lakes in different seasons with maximum richness during winter (10 *pats*) and autumn (5 *pats*) (Table 5). The last aspect is affirmed by significant inverse correlation between richness and water temperature (r = -0.441). Canonical analysis registers moderate cumulative influence of six abiotic factors (R = 0.529) on richness. Peak mean richness is noticed during winter (52 ±9 species), followed by 49 ±6 species during autumn while summer and monsoon communities record (34 ±4 species) lowest mean richness. The stated features are in contrast to higher richness reported during summer in the beels of the Brahmaputra basin (Sharma 2005).

Rotifer abundance is apparently low (58-188, 68 ±18 - 125 ±25 n/l) and it registers significant temporal variations between the *pats* ($F_{14.59} = 15.601$, $P < 0.005$), as well as between seasons ($F_{3.59} = 4.345$, $P < 0.005$). Relatively higher densities noticed in Loktak *pat* (84-188 n/l) and Waithou *pat* (87-198 n/l) are yet notably lower than their counterparts from Assam state (Sharma 2005). The rotifers comprise an important quantitative component (mean: 45.9-58.8%) of zooplankton in all lakes and, hence, correspond with the results of Sharma (2005) and Sharma and Sharma (2008), but differ from sub-dominant quantitative role reported by Sharma (2000). Rotifera abundance is inversely correlated with conductivity (r = -0.410) and alkalinity (r = -0.657) and is positively correlated with hardness (r = 0.614). Canonical analysis registers higher cumulative influence of six abiotic factors (R = 0.855) on abundance.

The rotifer communities of Manipur lakes indicate relatively higher species diversity (2.768 ±0.092 - 3.760 ±0.232) than their counterparts of Assam (Sharma 2005). Interestingly, Loktak lake (a Ramsar site) exhibits highest

Table 5: Seasonal variations in Rotifera richness

Lakes	Autumn	Winter	Summer	Monsoon	Range	Total Richness	Mean ± SD
Loktak	60	79	41	43	41-79	120	53 ± 15
Waithou	40	55	34	37	34-55	68	41 ± 5
Utra	45	40	32	28	28-45	66	36 ± 5
Sana	55	49	35	30	30-55	69	42 ± 10
Lakoi	42	48	29	34	29-48	63	38 ± 7
Takmu	47	40	30	32	30-47	62	37 ± 7
Ikop	46	50	33	35	33-50	70	41 ± 7
Kharung	52	59	31	40	31-59	82	45 ± 11
Khoidum	48	54	38	32	30-54	67	43 ± 8
Lousi	42	49	30	33	30-49	62	38 ± 8
Karam	52	48	37	31	31-52	70	42 ± 8
Ngagua	45	51	30	35	30-51	72	40 ± 8
Tankha	58	60	40	31	31-60	75	47 ± 12
Lamphel	46	51	35	30	30-51	70	40 ± 8
Pumlen	60	55	41	35	35-60	73	48 ± 10

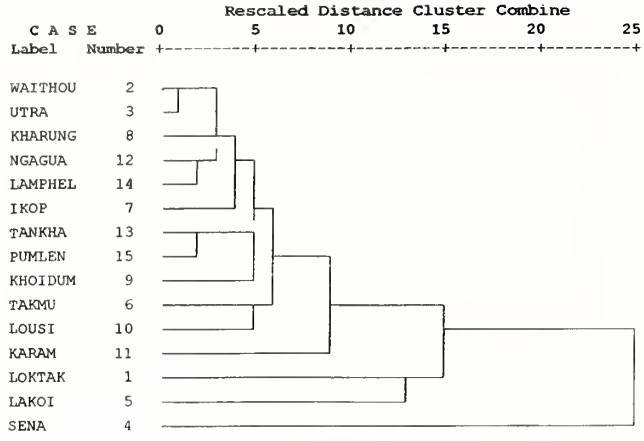

Fig. 2: Dendrogram showing hierarchial cluster analysis of Rotifer communities of different lakes of Manipur

species diversity (Table 6). The notable feature of higher species diversity with relatively lower densities of a large number of species observed in the present study may be ascribed to fine niche portioning amongst rotifer species in combination with high micro- and macro-scale habitat heterogeneity, especially in littoral environments as hypothesized by Segers (2008). Further, the present observations exhibit lower Rotifera dominance (mean: 0.069-0.114) signifying quantitative influence of fewer species (Table 6). The stated feature is re-affirmed by their higher evenness in various *pats* (mean 0.879-0.953) indicating an equitable abundance of different species (Table 6). Dominance is inversely correlated with density (r = -0.709). Evenness is inversely correlated with dominance (r = -0.926) while it is positively correlated with density (r = 0.575). The salient features of lower dominance and higher evenness concur with earlier remarks of Sharma (2000, 2005) and Sharma and Sharma 2008).

CONCLUSION

To sum up, Rotifera exhibit rich and diverse taxocoenosis with typical tropical character, show occurrence of several biogeographically interesting and acidophilus species and, form main qualitative and quantitative component of zooplankton in all the sampled *pats*. Richness and abundance register significant temporal variations between *pats* and seasons, record limited influence of individual abiotic factors while multivariate analysis indicates moderate and relatively higher cumulative impact of six abiotic factors on richness and density respectively. The rotifer communities of the different *pats* are characterized by relatively higher species diversity, lower dominance and higher evenness.

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Table 6: Rotifera Density, Species diversity, Dominance and Evenness

Lakes	Density (n/l)	Mean density (n/l)	Percentage	Species Diversity	Dominance	Evenness
Loktak	84-188	125 ±25	46.6 ±4.1	3.760 ±0.232	0.070 ±0.028	0.953 ±0.048
Waithou	87-198	119 ±25	53.5 ±3.1	3.507 ±0.128	0.069 ±0.013	0.946 ±0.023
Utra	65-135	87 ±22	45.9 ±4.7	3.375 ±0.081	0.075 ±0.018	0.943 ±0.028
Sana	70-139	91 ±20	54.5 ±3.6	3.007 ±0.110	0.092 ±0.012	0.902 ±0.019
Lakoi	80-167	102 ±27	57.3 ±3.3	2.901 ±0.079	0.085 ±0.021	0.923 ±0.026
Takmu	60-121	76 ±18	57.6 ±3.7	2.834 ±0.091	0.098 ±0.019	0.898 ±0.022
Ikop	63-128	81 ±20	54.4 ±3.6	2.891 ±0.101	0.112 ±0.027	0.879 ±0.031
Kharung	70-130	84 ±19	55.6 ±2.7	2.987 ±0.113	0.106 ±0.031	0.887 ±0.036
Khoidum	58-119	71 ±18	55.0 ±3.8	3.026 ±0.128	0.089 ±0.019	0.928 ±0.029
Lousi	60-124	72 ±21	54.5 ±3.4	3.020 ±0.099	0.092 ±0.026	0.929 ±0.034
Karam	65-127	89 ±19	55.2 ±3.9	3.103 ±0.106	0.095 ±0.037	0.903 ±0.025
Ngagua	60-110	70 ±16	58.8 ±3.5	3.060 ±0.098	0.114 ±0.022	0.899 ±0.030
Tankha	62-118	72 ±20	55.3 ±3.0	2.768 ±0.092	0.090 ±0.029	0.911 ±0.029
Lamphel	57-106	69 ±18	55.6 ±3.4	2.965 ±0.117	0.102 ±0.022	0.901 ±0.030
Pumlen	76-131	90 ±24	46.9 ±3.5	3.102 ±0.092	0.078 ±0.029	0.942 ±0.021

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